Temporal and Spatial Distributions of Cases of Verocytotoxigenic *Escherichia Coli* Infection in Southern Ontario

Pascal Michel (1),* Jeff Wilson (1,2), Wayne Martin (1), Scott McEwen (1), Robert Clarke (3), Carlton Gyles (4)

(1) Department of Population Medicine, OVC, University of Guelph, Guelph, Ontario, Canada; (2) Laboratory Centre for Disease Control, Health Canada, Canada; (3) Guelph Laboratory, Health Canada, Guelph, Ontario, Canada; (4) Department of Pathobiology, OVC, University of Guelph, Guelph, Ontario, Canada

Abstract

The distribution of 3,001 cases of verocytotoxigenic *Escherichia coli* (VTEC) reported in the province of Ontario, Canada, was examined to describe the magnitude of this condition geographically and to evaluate the spatial relationship between livestock density and human VTEC incidence using a geographical information system (GIS). Incidence of VTEC cases had a marked seasonal pattern with peaks in July. Areas with a relatively high incidence of VTEC cases were situated predominantly in areas of mixed agriculture. Spatial analyses were done for the southern regions of the province. Spatial models indicated that cattle density had a positive and significant association with VTEC incidence of reported cases (p=0.000). An elevated risk of VTEC infection in rural population could be associated with living in areas with high cattle density. Results of this study suggested that the importance of contact with cattle and the consumption of contaminated well water or locally produced food products may have been previously underestimated as risk factors for this condition.

Keywords: VTEC, mapping, surveillance, spatial analysis, cattle density

Introduction

Data on 3,001 verocytotoxigenic *Escherichia coli* (VTEC) cases reported in Ontario, Canada, from January 1990 to December 1995 were extracted from the Ontario Ministry of Health's Reportable Disease Information System database. Cases of VTEC infection are defined as persons with compatible clinical signs for which verocytotoxin was detected from stool specimens; persons with compatible clinical signs and for which one or more strains of VTEC was isolated from stool or blood; or, any symptomatic person with an epidemiologic link to two or more laboratory-confirmed VTEC cases. Farm animal distributions and land use data were obtained from the 1991 Census of Agriculture for Ontario (1).

Spatial Regression and Mapping

All cartographic outputs were produced by ArcView 3.1 (ESRI, Redlands, CA). In addition to providing a relational linkage between databases and the production of maps,

* Dr Pascal Michel, Health Canada, Quebec, Canada; (p) 450-773-8521 x8475; (f) 450-778-8120; E-mail: pascal_michel@hc-sc.gc.ca

the software was used to perform several spatial manipulations including the calculation of the county's total area and centroid coordinates (latitude and longitude), the Euclidian and geographical distances between each pair of counties, and the production of contiguity and inverse distance matrices used for spatial autocorrelation and regression. The Moran's I (2) and G statistics were calculated to explore the spatial distribution of VTEC cases across the 49 counties of Ontario (Figure 1).

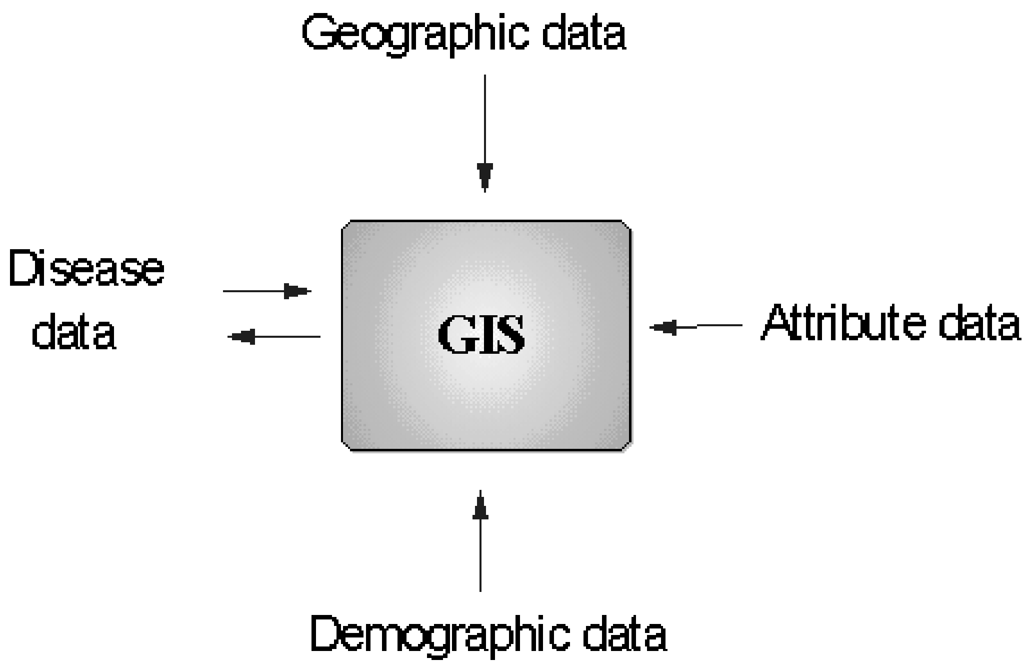

Figure 1 Sources of data.

Variables used in the modeling process included proportion of the total land that is cultivated (PCULTI); cattle density (TCDENS); dairy cattle density (TDDENS); density of livestock other than cattle (NOCATDENS); and livestock density (AUDENS) (3). An additive seasonal variation model was used to describe the temporal variation of VTEC cases over the six-year study period. This model includes a trend (Tt), a seasonal effect (St), and an error component (It) (Figure 2).

Geographical Distribution

The Moran's I index indicated an overall significant spatial autocorrelation of VTEC incidence in Ontario regardless of the underlying null distribution or the weight matrix chosen for the calculation ($p < 0.005$). For most regions, the geographic distribution of cattle density by county presented a geographic pattern similar to the one described for human VTEC cases (Figure 3). Counties with higher cattle density were located in three different areas of Ontario (Figure 4).

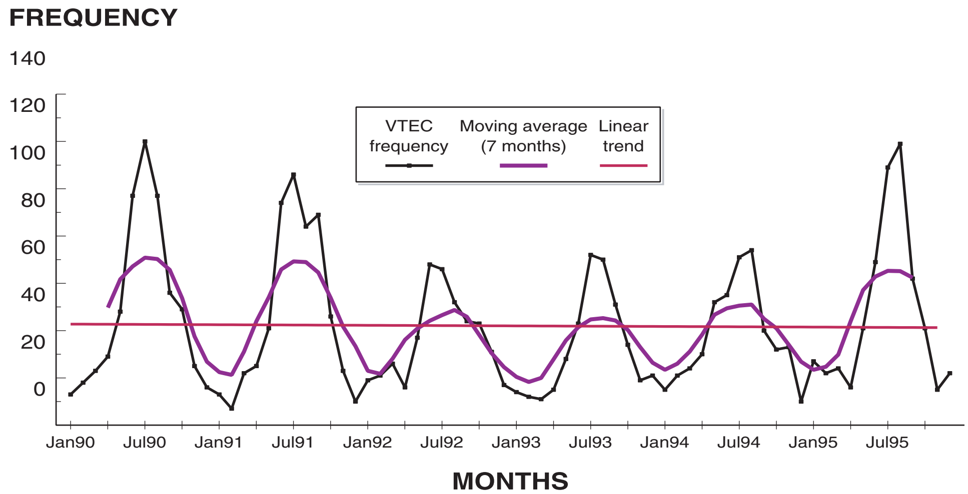

Figure 2 Linear trend and moving average for VTEC time-series, Ontario, Canada, 1990–1995.

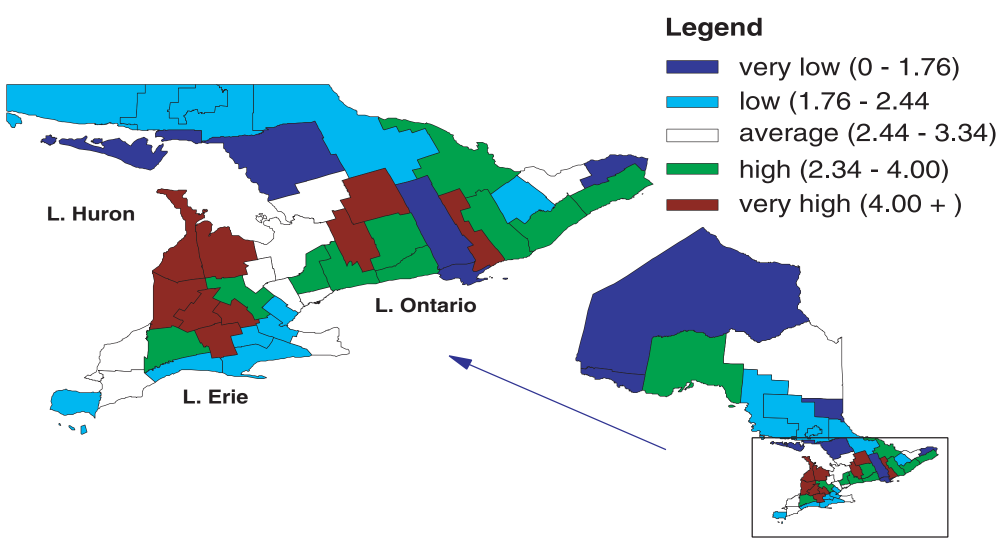

Figure 3 VTEC incidence in Ontario, Canada, 1990–1995. Direct standardized VTEC rates per county (per 10,000 population).

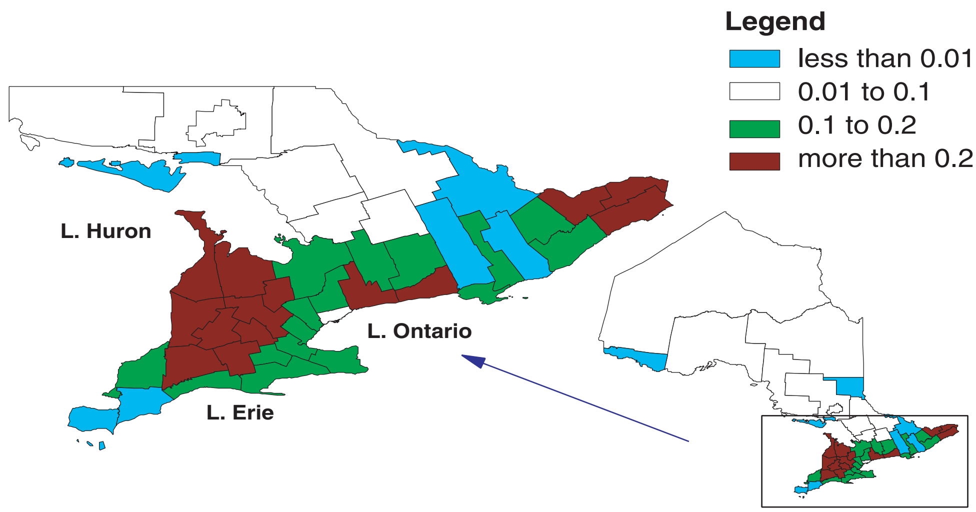

Figure 4 Cattle density in the Province of Ontario. Total cattle per hectare of total land.

Spatial Regression

In the first spatial regression approach, southern regions (south, west, central, and east) were analyzed separately from the northern region. The northern section of Ontario was omitted from the analysis. Besides the spatial error coefficient—latitude (YCOORD) and longitude (XCOORD)—the best predictors for the southern models included cattle density (TCDENS) (p=0.012) in a first model (A) and livestock density (AUDENS) (p=0.005) in a second model (B). In these models, the strong effect of latitude and longitude variables suggested some meaningful and undescribed spatial process influencing the outcome.

In the second approach, a spatial regimes model (4,5) was implemented to take into consideration different intercepts and/or slopes in the regression equation for the five agricultural regions of Ontario. The variable selection process resulted in a third model that included only the explanatory variable "total cattle density." Positive and significant coefficients representing the regional effects of cattle density on the incidence of human VTEC cases were calculated for the southern and western regions and negative and significant coefficients were associated with the eastern and northern regions. A positive but not statistically significant coefficient was estimated for the cattle-VTEC relationship in the central region.

Time Distribution

Observed rates of VTEC cases and predicted values from the additive seasonal model are presented in Figure 2. Visual assessment shows that the model fit the observed values closely, with some underestimation for the summers of 1990, 1991, and 1995 (coefficient of determination for the model: R=71.4%).

Conclusion

Results of the present study suggest that farm animal density, and particularly cattle density, is a significant predictor of human VTEC incidence in many regions of Ontario. This finding supports the possibility that direct and indirect human contact with reservoir animals is an important mode of transmission of VTEC organisms. In areas with higher cattle density, factors that could be responsible for VTEC transmission include the contamination of surface water and shallow wells by cattle manure; working with, or being in close contact with cattle; and, consumption of food produced and processed locally. It is understood that, under the limitations of the present study design, the observed association between human VTEC incidence and cattle density may not be causal. The importance, however, of such information for the public health and agriculture sectors underscores the need to promote further studies, including specific evaluations of the comparative risk of disease acquisition between rural and urban human populations, as well as investigations of environmental risk factors associated with human exposure to the cattle.

The temporal distribution of human VTEC cases reported in Ontario is regular with one seasonal peak in mid-summer. The regularity in the provincial cyclical pattern generated a very good fit between the observed monthly VTEC incidence and the expected level based on an additive seasonal variation model. A secondary objective in estimating the seasonal model was to provide reference values for a comparison of observed regional VTEC incidence and a 95% prediction interval based on the Ontario model. For most areas, the model could therefore be used to monitor observed surveillance data and point out unexpected temporal clusters of VTEC cases in a given region.

Future Directions

The national technical steering committee on foodborne, waterborne, and enteric disease surveillance of the Laboratory Centre for Disease Control (LCDC), Health Canada, has recently suggested that the project on the geographic surveillance of VTEC data in Ontario be expanded nationally to include other reportable enteric conditions such as campylobacteriosis and salmonellosis. This impulse has lead to the development of the National GIS Enteric Surveillance Initiative. The main objective of this initiative is to develop the capabilities and expertise to analyze and interpret geographically referenced surveillance data on priority foodborne pathogens with corresponding demographic and environmental information, and to make use of these resources in various surveillance activities and targeted studies in collaboration with public health partners. The initiative is also closely linked with various components of the National Health Surveillance Infostructure, which is supporting the development of a nationally integrated electronic health information network and includes the Canadian Integrated Public Health System (CIPHS), the Spatial Public Health Information eXchange (SPHINX), and the Geomatic Information System Infrastructure. The current research focus of the GIS surveillance initiative includes the epidemiology of high priority foodborne and waterborne enteric pathogens, the antimicrobial resistant enteric organisms transmitted from food and animals to humans, and the development of indices describing the environmental hygienic pressure linked to intense agriculture and livestock density.

Acknowledgments

The authors gratefully acknowledge Dr C Leber and Dr J Carlson of the Ontario Ministry of Health, the Medical Officers of Health of the regional health units of Ontario, Dr B MacDonald of Agriculture and Agri-Food Canada, Guelph, the Laboratory Centre for Disease Control (LCDC), Health Canada, and the agroecosystem research group of the University of Guelph for their participation in this study.

References

1. Statistics Canada. *1991 census of agriculture for Ontario*. Statistics Canada.
2. Moran P. 1948. The interpretation of statistical maps. *Journal of the Royal Statistical Society* B10:243–51.
3. Ministry of Agriculture and Food, Ministry of the Environment, Ministry of Housing of Ontario. 1996. *Agricultural Code of Practice.* 14–15.
4. Quandt R. 1958. The estimation of parameters of a linear regression system obeying separate regimes. *Journal of the American Statistical Association* 53:873–80.
5. Anselin L, Hudak S. 1992. Spatial econometrics in practice: A review of software options. *Regional Science and Urban Economics* 22:509–36.